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ORIGINAL ARTICLE

Quality of life in children operated for spina bifida; low- and middle-income country perspective

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Abstract

Introduction Spina bifida is a potentially disabling congenital condition and affects the quality of life (QOL). We aimed to assess clinical outcomes and QOL in children who underwent spina bifida repair at our hospital.

Methods This was a retrospective cohort study on children who underwent spina bifida repair at our hospital over 10 years. Phone calls were made to parents of the children, and the Health Utility Index Mark 3 (HUI 3) score was used to assess QoL, and degree of disability. Demographics and clinical data were obtained from the medical chart review. Statistical analysis was done using SPSS (version 21).

Results Eighty children with a median age of 1.1 months (IQR 0.03–2.0) at the time of presentation, were included in this study. The mean follow-up period was 6.04 ± 2.54 years and the median HUI-3 score was 0.64 (IQR: 0.40 – 0.96) on a scale of 0 (dead) to 1 (perfectly healthy). Based on the severity of disability, 12 (23.1%) children had mild disability, 4 (7.7%) had moderate disability, and 23 (44.2%) had severe disability. Factors including a leaking spina bifida and paraplegia at presentation; radiological findings of hydrocephalus and Chiari malformation, were associated with a significantly low QOL. Children who required CSF diversion (EVD/ VP shunt) during the repair or at a later stage also had significantly low QOL.

Conclusion In LMIC, children with myelomeningocele (MMC) born with lower limb weakness, hydrocephalus, Chiari malformation, and those presenting with leaking MMC, have a significantly low QoL at a mean follow-up of 6 years.

Keywords Myelomeningocele · Quality of Life · Spina Bifida · Outcomes

Introduction

During the last few decades, the global incidence of spina bifida has considerably decreased due to folic acid supplementation in diet [1]. However, it is still one of the most common causes of childhood disability and can affect the quality of life (QOL), particularly in low- and middle-income countries (LMIC). Early surgical intervention does not warrant complete neurological recovery, even though it is crucial to prevent long-term problems, most children would remain

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dependent on caregivers [2]. More than half of these children have additional associated neurological conditions, as well as non-neurological congenital anomalies, which further hinder their efforts to live a normal life [3].

QOL is an individual's perception of life, in the context of value systems, culture, expectations, concerns, and standards, within the confines of his or her environment [4]. Any medical condition that causes temporary or permanent disability can affect the health related QOL. In the United States, first-year survival rate of infants with spina bifida has increased to 92%, and 75% reach adulthood [1]. As life expectancy has improved, more patients with spina bifida experience social, emotional, cognitive, and psychological distress [5, 6]. Limited resources, financial constraints, absence of support groups, and lack of access to rehabilitation centers result in a greater negative impact of spina bifida on the health related QOL in LMICs [2]. The true incidence of spina bifida in Pakistan is not known, however, available data estimate the incidence of neural tube defects (NTDs) between 38.6 and 124.1 per 10,000 births, which is significantly higher than the global average of 10 per 10,000 births [7]. Pakistan is the 5th most populous country in the world, and the incidence of myelomeningocele (MMC) is high due to the limited access to prenatal screening, lack of folate-fortified food, unavailability of folate supplements, and consanguineous marriages.

While surgical outcomes for spina bifida have been widely reported, there is a dearth of data from LMICs on the long-term health related QOL in these patients [2]. Considering the high prevalence of spina bifida in the country, and a nearly non-existent disability support system in the country, we aimed to study the operative outcomes and QOL in patients who were operated on for spina bifida at our hospital during the last ten years, and to seek predictors diminished QOL.

Methods

This was a retrospective cohort study. The study population comprised patients who were operated on for spina bifida at the Aga Khan University, from January 2011 to December 2020. These patients included those who were diagnosed with meningocele and myelomeningocele. Cases were identified using the ICD-10 codes. Ethical approval was obtained from the Ethical Review Committee at the University before initiating the study. We identified 80 patients who fulfilled the inclusion criteria. Medical records of these patients were reviewed for collecting information about their birth history, demographics, neurological status, details of the surgery, and clinical outcomes. Contact information of parents was obtained from the hospital record, and phone calls were made to collect the information on the QoL of these patients at the time of data collection. Two subsequent attempts were made to contact parents who did not respond to the first phone call. Verbal consent was obtained over the phone.

We used the Health Utility Index Mark 3 (HUI-3) for calculating the QOL of these patients [8]. HUI-3 is a comprehensive validated tool consisting of 8 components for measuring health-related QOL and has been used extensively in both healthy and chronically ill pediatric and adult populations to describe health states. The questionnaire is designed for both self- and proxy administration. It gives a quantitative score on a scale of 0 (dead) to 1 (perfect health) after taking patients' vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain into account. A score for each attribute is assessed based on the participant's choice of 4–5 responses, and normative scores are based on population preferences for levels of optimal health across the 8 domains. Using the HUI3-defined scoring algorithms, single-attribute scores can then be compiled to determine an overall multi-attribute score. Multi-attribute scores, which encompass all domains concurrently and account for the interaction between attributes, are calculated to derive an estimation of the participant's overall HRQOL.

Statistical analysis was done using SPSS version 22. For categorical variables frequencies and proportions were calculated, whereas means and standard deviation or median and interquartile ranges were calculated for continuous variables. The data was not normally distributed so non-parametric tests were applied. Mann-Whitney U-test was used for the comparison of HUI-3 scores. For comparison of QOL scores between more than 2 categories, the Kruskal–Wallis test was used. Correlation between continuous variables was assessed using the Spearman rho correlation coefficient. When a continuous variable, such as age, was a potential confounder for a categorical variable, we performed the ANOVA test. A cutoff of $p < 0.05$ was taken as significant.

Linear regression was used to determine the factors associated with a poor QoL, and unadjusted and adjusted beta coefficients, standard error (SE), and 95% confidence interval (CI) were calculated. All plausible interactions were considered, and independent variables with a p-value < 0.25 on univariate analysis were included in the multivariable model. A p-value < 0.05 was considered significant.

Results

The median age of the patients at the time of presentation was 1.1 months, whereas the median age at the time of data collection was 6 years, with a slight male predominance (n = 50; 62.5%). Most children were born at full term (48; 60%). Only 15 (18.8%) mothers had regularly taken folate supplements

during pregnancy, but we could not confirm whether they had started the supplements before conception or after confirmation of pregnancy. MMC was the most common subtype of spina bifida in our cohort (65; 81.2%), and 36 (43.8%) patients had CSF leakage at presentation. Hydrocephalus was the most commonly associated condition seen in 40 (51.3%) patients. Parents of 52 patients responded to phone calls. Table 1 contains further details of presenting features.

Fifty-one patients (63.8%) had CSF diversion, out of which 26 (32.5%) patients had permanent diversion in the form of a VP shunt. Placement of EVD at the time of repair ($p = 0.012$) or the need for a CSF diversion at a later stage ($p = 0.029$) were associated with a significant decrease in QOL (Table 2). Post-operative CSF leak from the wound was the most common surgical complication (9; 11.3%). Table 2 mentions details of surgical procedures and clinical outcomes.

The mean follow-up period was 6.04 ± 2.54 years and the median HUI-3 score was [0.64 (IQR: 0.40 – 0.96)]. Furthermore, based on the severity of disability 13 (25%) children had no disability (HUI-3 score: 1), 12 (23.1%) children had a mild disability (HUI-3 score: 0.99- 0.89), 4 (7.7%) children had moderate disability (HUI-3 score: 0.88- 0.70), and 23 (44.2%) children had a severe disability (HUI-3 score: < 0.70).

At the time of presentation, a leaking spina bifida ($p < 0.001$), motor weakness in lower limbs ($p = 0.004$), and incontinence ($p = 0.042$) were associated with a significant decrease in QOL. On imaging hydrocephalus ($p < 0.001$) and Chiari malformation ($p = 0.007$) were associated with significantly lower QOL (Table 1). At subsequent follow-ups lower limb motor weakness ($p = 0.019$), incontinence ($p = 0.044$), and a need for a new procedure (0.022) were associated with significantly lower QOL (Table 2).

Table 1 Demographics & Presenting Features

Parameters	Results	P Value
Median age	1.1(IQR: 0.03 – 2.0) months	
Gender	Male: 50 (62.5%) Female: 30 (37.5%)	P = 0.570
Time of mother's delivery	Pre-term: 4 (5%) Term: 48 (60%) Missing information: 28 (35%)	P = 0.986
Mean age of mother at the time of child's birth	28.6 ± 5.3 years	P = 0.319
Folate consumption before conception	Regular intake: 15 (18.8%) Irregular intake: 27 (33.8%) No intake: 10 (12.4%) Did not remember: 28 (35%)	P = 0.887
Antiepileptic use during pregnancy	2 (1.8%)	P = 0.923
Type of neural tube defect	Meningocele: 15 (18.8%) Myelomeningocele: 65 (81.2%)	P = 0.928
Location of neural tube defect (NTD)	Thoracic: 7 (8.8%) Lumbar: 26 (32.5%) Lumbosacral: 44 (55%) Sacral: 3 (3.7%)	P = 0.144
CSF leakage before repair	36 (43.8%)	P < 0.001*
Lower extremity motor function at presentation[a]	Grossly intact (moving against gravity): 52 (65%) Incomplete weakness (moving along gravity): 8 (10%) Complete weakness: 20 (25%)	P = 0.004*
Sphincter function at presentation	Grossly intact: 27 (33.7%) Impaired: 16 (20%) Missing information: 37 (46.3%)	P = 0.042*
Associated conditions on initial imaging		
Hydrocephalus	40 (51.3%)	P = 0.001*
Diastematomyelia	12 (15.4%)	P = 0.052
Epidermoid/Dermoid lesion	3 (3.8%)	P = 0.420
Radiologically proven Chiari malformation	45 (57.7%)	P = 0.007*
Median HUI3 score (for 74 patients who responded on the phone)	0.64 (IQR: 0.40 – 0.96)	

*Significant

[a]Spontaneous, adequate movements at hips and knees

Table 2 Details of Surgical Procedures & Outcomes

Parameters	Results	P Value
Primary surgery	Spina bifida repair with primary wound closure: 59 (73.8%) Spina bifida repair with skin flap: 21 (26.2%)	P = 0.091
CSF diversion at the time of spina bifida repair	Total: 20 (25%) EVD: 15 (18.8%) VP shunt: 5 (6.2%)	P = 0.012* P = 0.676
CSF diversion at a later stage	Total: 31 (38.8%) EVD insertion only: 4 (5%) VP shunt insertion only: 21 (26.3%) Both EVD and VP shunt: 6 (7.5%)	P = 0.029*
CSF diversion and admissions	During the same admission: 12 (15%) In another admission: 19 (23.8%)	P = 0.259
Median duration between NTD repair and EVD insertion	9.0 (IQR: 2.0 – 23.0) days	P = 0.448
Median duration between NTD repair and VP shunt insertion	8.5 (IQR: 4.75 – 17.75) days	P = 0.520
Median length of hospital stay	10.7 (IQR: 5.0 – 13.0) days	P = 0.102
Complications of surgery		
CSF leak	9 (11.3%)	P = 0.523
Meningitis	6 (7.5%)	P = 0.147
Wound dehiscence	4 (5%)	P = 0.366
Seizures	4 (5%)	P = 0.188
Mean follow-up in neurosurgery clinic	6.0 ± 2.54 years	
Lower extremity motor function at last follow-up	Intact: 55 (68.8%) Incomplete weakness: 11 (13.8%) Complete weakness: 14 (17.4%)	P = 0.019*
Sphincter function at last follow-up	Intact: 19 (23.8%) Impaired: 8 (10%) Missing information: 53 (66.2%)	P = 0.044*
Total number of surgeries to date	One: 47 (58.8%) Two: 27 (33.7%) Three: 3 (3.7%) More than three: 3 (3.8%)	P = 0.022*
Mortality during the follow-up period	9 (11.25%)	P < 0.001

*Significant

Linear regression analysis

On univariate linear regression with QoL as the dependent variable, children presented with hydrocephalus (Beta Coefficient: -0.352), Chiari malformation (-0.261), a leaking spina bifida (-0.401) were negatively associated with QoL. Folate intake during pregnancy (0.057) and power in lower limbs (0.178) were positively associated with QOL. An intraoperative need for EVD (-0.358) and any subsequent need for a CSF diversion procedure was negatively associated with QOL. Postoperative development of hydrocephalus (-0.457), meningitis (-0.362), and seizures (-0.448) were negatively associated with QOL.

On multivariable linear regression, power in lower limbs on presentation (0.205) and discharge (0.270) were positively associated with QOL. Whereas a leaking spina bifida (-0.304) at presentation was negatively associated with QOL (Table 3).

Discussion

This is one of the very few studies from LMICs that report health-related QOL in children with spina bifida. We included 114 children, with a median age of 1.5 months and assessed pre-surgical and post-surgical factors which could significantly correlate with a low HIU 3 score, representing poor quality of life. Pre-surgically, the presence of CSF leak, weakness in lower limbs, presence of hydrocephalus, and Chiari malformation were factors that were significantly associated with a low mean HIU 3 score. Among the operative and post-surgical outcomes, the development of hydrocephalus during the hospital stay and CSF diversion either during the time of MMC repair or at a later stage were significantly related to poor QOL.

MMC is one of the most common congenital malformations of the CNS causing a spectrum of morbidity [9]. The condition has both physical and psychological consequences

Table 3 Multiple regression analysis of factors predicting quality of life in children with spina bifida

Factors	Univariate Regression Model				Multivariate Regression Model			
	Unstandardized coefficient (B)	Sig.	95% CI for B		Unstandardized coefficient (B)	Sig.	95% CI for B	
			Lower bound	Upper bound			Lower bound	Upper bound
(constant)					0.797	< 0.001	0.450	1.144
Folate Intake	0.057	0.180	-0.027	0.140	0.017	0.685	-0.102	0.068
Power of lower limb on presentation	0.178	0.004	0.059	0.297	0.205	0.003	-0.063	0.223
Leaking spina bifida	-0.401	< 0.001	-0.587	-0.215	-0.304	0.022	-0.561	-0.047
Hydrocephalus on imaging	-0.352	< 0.001	-0.540	-0.165	-0.169	0.162	-0.410	0.071
Chiari Malformation	-0.261	0.014	-0.468	-0.054	0.018	0.879	-0.215	0.250
Insertion of EVD at the time of repair	-0.358	0.006	-0.607	-0.108	-0.152	0.354	-0.481	0.177
Post-operative need for a CSF diversion procedure	-0.219	0.041	-0.428	-0.009	-0.037	0.767	-0.212	0.285
Power in lower limb on discharge	0.155	0.021	0.025	0.286	0.270	0.021	-0.161	0.701
Hydrocephalus during the hospital stay	-0.457	0.009	-0.793	-0.121	-0.095	0.662	-0.534	0.343
Meningitis during the hospital stay	-0.362	0.108	-0.805	0.082	-0.022	0.921	-0.476	0.431
Postoperative seizures	-0.448	0.100	-0.985	0.089	0.306	0.443	-0.495	1.107

that last throughout the patient's lifetime. Surgical management should be followed by regular and comprehensive specialist evaluations to detect complications followed by prompt management to improve the negative impact of the condition [10]. North et al. compared two 10-year cohorts of MMC patients in Canada; the first cohort from 1971–1981 included 101 patients, and the second cohort from 1996 to 2006 included 46 patients. The factors that had significantly improved in the second cohort were MMC incidence, mortality, and the proportion of cases operated within 48 h of birth. However, the long-term functional outcomes did not improve between the two groups [11].

Although the true incidence of MMC in Pakistan is unknown, current literature suggests that the incidence of NTDs is between 38.6 and 124.1 per 10,000 births [7]. Developing countries like Pakistan where there is suboptimal health resource utilization, and literacy is low, have a higher number of cases of NTDs [12]. Khan et al. conducted a cross-sectional study on 67 patients born with spina bifida at a large public sector hospital. They reported that a majority of mothers of MMC patients belonged to a low socio-economic background and had not had a prenatal evaluation during the first trimester, indicating a higher probability of these mothers missing folate supplementation and antenatal screening [13]. In our study only 18.8% of the mothers recalled taking regular folate supplementation before conception, highlighting inadequate maternal folic acid supplementation as a risk factor in MMC patients which is comparable with previous research conducted in Pakistan [13–17]. Mandatory food fortification laws have been passed since 2021 in two provinces of Pakistan. Similar interventions focused on reducing barriers to folic acid supplementation such as providing adequate awareness, excellent quality counseling, and availability of free supplements throughout pregnancy should be implemented to reduce the incidence of NTDs [18].

The Health Utilities Index (HUI) is a classification system that provides a compact but comprehensive framework to describe health status [19]. With a mean follow-up of 6.04 ± 2.54 years, 52 caregivers of MMC patients responded to phone calls in our study, and the mean HUI-3 score was measured as 0.64 ± 0.37 [8]. Young et al. measured the health outcomes in Canadian spina bifida patients (40 children and 13 young adults) and reported the mean HUI3 score as 0.52 [20]. Their results are similar to another Canadian study on MMC patients by Karmur et al., which included 131 patients with shunted hydrocephalus, and reported the mean HIU3 score as 0.51 [21]. A study on the QOL of Ugandan children with MMC reports the mean HUI3 score by 66 caregivers as 0.549 (95% CI 0.465 to 0.633) [2]. Our mean HUI 3 score falls in the severe disability category similar to the results from other high-income countries and LMIC.

Preoperative motor weakness in lower limbs in our patients was significantly correlated to a lower HIU3 score.

A study from Turkey reported QOL in 50 children with MMC and used CHQ-PF-50 (Child Health Questionnaire Parent Form 50) to assess QOL. They found that non-ambulatory MMC patients had a significantly lower QOL compared to ambulatory patients [22]. We investigated the co-morbidities present on initial imaging and found that the presence of hydrocephalus and Chiari malformation was significantly correlated to a lower QOL. Rozensztrauch et al. in a recent study interviewed 52 parents of children with MMC and reported a similar correlation between hydrocephalus and the QOL, as patients with no hydrocephalus functioned significantly better than patients who had this defect in the physical, social, and school areas [10]. A significant proportion of MMC patients develop hydrocephalus and require some form of CSF diversion, with shunt rates varying from 52 to 92% [23]. Several studies have reported a significant negative impact of shunted hydrocephalus on QOL ranging from neuropsychological to sports and physical functioning [1, 24–27]. There have been concerns about the simultaneous repair of MMC and shunt insertion related to an increased rate of post-surgical complications [28]. However, in our cohort, both early and late CSF diversion was negatively associated with QOL.

There were some limitations of this study. We report patients from a single tertiary care private medical center. There is a high probability of the patients belonging to middle and high socio-economic backgrounds which means better health and social determinants which led to relatively better health outcomes. Hence, our results might not represent MMC patients from across the country. This was a retrospective study which creates a possibility of recall bias as caregivers were contacted over the telephone about patients initially presenting many years ago for example 35% of the mothers could not recall whether they had taken regular folic acid supplementation. Additionally, we noticed that a high number of children in our study underwent an EVD as a form of temporary CSF diversion, and none of the children underwent either an ETV (endoscopic third ventriculostomy), insertion of a VAD (ventricular access device), or an intrauterine repair. This represents the practice preferences of some of our neurosurgeons. Our hydrocephalus and shunt insertion rates were much lower than that reported in the literature, which may be due to underdiagnosis, and losing patients to follow-up. We also had a much lower rate of multiple surgeries in our patients, which may be attributed to a shorter mean follow-up rate, and a significant loss to follow-up rate in our patients. The loss to follow-up is an often reported problem in most studies coming out from LMIC, and unless a registry is maintained and these children are actively followed up for the late sequel of MMC, the problem will tend to stay.

Conclusion

Spina bifida is a potentially disabling condition that significantly impacts QOL in children. Children presenting with weakness in lower limbs, hydrocephalus, Chiari malformation, and leaking MMC have a significantly low QoL. Preventive strategies including better antenatal care and folate supplementation should be encouraged.

Abbreviations QoL: Quality of Life; LMIC: Low- and middle-income countries; HUI 3: Health Utility Index Mark 3; NTDs: Neural tube defects; MMC: Myelomeningocele; SE: Standard error; CI: Confidence interval; HUI: Health Utilities Index; CHQ-PF-50: Child Health Questionnaire Parent form 50; ETV: Endoscopic third ventriculostomy; VAD: Ventricular access device

Authors' contributions Mujtaba Khalil, Saqib Kamran Bakhshi and Zara Shah conceived and designed the project, and wrote the manuscript. Shilpa Golani and Hassaan Musood collected data. Faiza Urooj and Nida Zahid performed the analysis. Michael Christopher Dewan and Muhammad Shahzad Shamim reviewed the manuscript.

Availability of data and material The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval The study has been approved by the institutional ethics research committee at Aga Khan University Hospital.

Consent to participate/publication Informed consent was obtained from legal guardians.

Conflict of interests The authors have no relevant financial or non-financial interests to disclose.

References

1. Rocque BG, Bishop ER, Scogin MA, Hopson BD, Arynchyna AA, Boddiford CJ et al (2015) Assessing health-related quality of life in children with spina bifida. J Neurosurg Pediatr 15(2):144–149. https://doi.org/10.3171/2014.10.PEDS1441
2. Sims-Williams HJ, Sims-Williams HP, Mbabazi Kabachelor E, Warf BC (2017) Quality of life among children with spina bifida in Uganda. Arch Dis Child 102(11):1057–1061. https://doi.org/10.1136/archdischild-2016-312307
3. Chakraborty A, Crimmins D, Hayward R, Thompson D (2008) Toward reducing shunt placement rates in patients with myelomeningocele. J Neurosurg Pediatr 1(5):361–365. https://doi.org/10.3171/PED/2008/1/5/361
4. World Health Organization (2002) WHOQOL-HIV instrument: scoring and coding for the WHOQOL-HIV instruments: users manual. World Health Organization
5. Sawin KJ, Bellin MH (2010) Quality of life in individuals with spina bifida: a research update. Dev Disabil Res Rev 16(1):47–59. https://doi.org/10.1002/ddrr.96
6. Rofail D, Maguire L, Kissner M, Colligs A, Abetz-Webb L (2013) A review of the social, psychological, and economic burdens experienced by people with spina bifida and their caregivers. Neurol Ther 2(1–2):1–12. https://doi.org/10.1007/s40120-013-0007-0

7. Rehman L, Shiekh M, Afzal A, Rizvi R (2020) Risk factors, presentation and outcome of meningomyelocele repair. Pak J Med Sci 36(3):422–425. https://doi.org/10.12669/pjms.36.3.1237
8. Feeny D, Furlong W, Torrance GW, Goldsmith CH, Zhu Z, DePauw S et al (2002) Multiattribute and single-attribute utility functions for the health utilities index mark 3 system. Med Care 40(2):113–128. https://doi.org/10.1097/00005650-200202000-00006
9. Yamashiro KJ, Galganski LA, Hirose S (2019) Fetal myelomeningocele repair. Semin Pediatr Surg 28(4):150823. https://doi.org/10.1053/j.sempedsurg.2019.07.006
10. Rozensztrauch A, Iwanska M, Baglaj M (2021) The Quality of Life of Children with Myelomeningocele: A Cross-Sectional Preliminary Study. Int J Environ Res Public Health 18(20). https://doi.org/10.3390/ijerph182010756
11. North T, Cheong A, Steinbok P, Radic JA (2018) Trends in incidence and long-term outcomes of myelomeningocele in British Columbia. Childs Nerv Syst 34(4):717–724. https://doi.org/10.1007/s00381-017-3685-6
12. Fayyaz M, Khushdil A, Baqai S (2020) Neural tube defects, their implications and solutions in Muslim society. J Pak Med Assoc 6:1–8. https://doi.org/10.47391/JPMA.669
13. Khan B, Khan MU, Ullah W, Ullah A, Ali M (2017) Maternal Concepts and Practices of Antenatal Care in Patients with Spinal Dysraphism. Pak J Neuro Surg 21(3):150–154
14. Fatima U, Gul S, Quddus I, Mehdi SH (2022) Awareness of maternal folate intake and prenatal screening in reducing the incidence of Myelomeningocele: a cross sectional study. PJMHS 16(1):40–42
15. Brohi AR, Brohi SR, Khaskheli MS (2008) Pattern and Frequency of Craniospinal anomalies. J Surg Pak (International) 13(2):67–70
16. Saleem M, Ali M, Hussnain Q (2010) Prevalence and Associated Risk Factors for Neural Tube Defects in Patients at Sheikh Zayed Hospital Rahim Yar Khan. Pakistan J Medical Health Sci 4(3)
17. Jamali MA, Naz A, Mari AR, Brohi SR, Jamali S, Wagan FF, Jamali AA (2020) Frequency of Neural Tube Defects Among 1000 pregnant women delivering at PMC Hospital Nawabshah. Journal of Peoples University of Medical & Health Sciences Nawabshah. (JPUMHS) 10(3)
18. Nisar YB, Alam A, Aurangzeb B, Dibley MJ (2014) Perceptions of antenatal iron-folic acid supplements in urban and rural Pakistan: a qualitative study. BMC Pregnancy Childbirth 14:344
19. Horsman J, Furlong W, Feeny D, Torrance G (2003) The Health Utilities Index (HUI): concepts, measurement properties and applications. Health Qual Life Outcomes 1:54. https://doi.org/10.1186/1477-7525-1-54
20. Young NL, Sheridan K, Burke TA, Mukherjee S, McCormick A (2013) Health outcomes among youths and adults with spina bifida. J Pediatr 162(5):993–998. https://doi.org/10.1016/j.jpeds.2012.10.042
21. Karmur BS, Kulkarni AV (2018) Medical and socioeconomic predictors of quality of life in myelomeningocele patients with shunted hydrocephalus. Childs Nerv Syst 34(4):741–747. https://doi.org/10.1007/s00381-017-3691-8
22. Seker Abanoz E, Ozmen M, Caliskan M, Gokcay G, Aydinli N (2020) Ambulation, lesion level, and health-related quality of life in children with myelomeningocele. Childs Nerv Syst 36(3):611–616. https://doi.org/10.1007/s00381-019-04348-0
23. Phillips BC, Gelsomino M, Pownall AL, Ocal E, Spencer HJ, O'Brien MS et al (2014) Predictors of the need for cerebrospinal fluid diversion in patients with myelomeningocele. J Neurosurg Pediatr 14(2):167–172. https://doi.org/10.3171/2014.4.PEDS13470
24. Battibugli S, Gryfakis N, Dias L, Kelp-Lenane C, Figlioli S, Fitzgerald E et al (2007) Functional gait comparison between children with myelomeningocele: shunt versus no shunt. Dev Med Child Neurol 49(10):764–769. https://doi.org/10.1111/j.1469-8749.2007.00764.x
25. Flanagan A, Gorzkowski M, Altiok H, Hassani S, Ahn KW (2011) Activity level, functional health, and quality of life of children with myelomeningocele as perceived by parents. Clin Orthop Relat Res 469(5):1230–1235. https://doi.org/10.1007/s11999-010-1651-7
26. Hampton LE, Fletcher JM, Cirino PT, Blaser S, Kramer LA, Drake J et al (2011) Hydrocephalus status in spina bifida: an evaluation of variations in neuropsychological outcomes. J Neurosurg Pediatr 8(3):289–298. https://doi.org/10.3171/2011.6.PEDS10584
27. Ramachandra P, Palazzi KL, Skalsky AJ, Marietti S, Chiang G (2013) Shunted hydrocephalus has a significant impact on quality of life in children with spina bifida. PMR 5(10):825–831. https://doi.org/10.1016/j.pmrj.2013.05.011
28. Machado HR, Santos de Oliveira R (2004) Simultaneous repair of myelomeningocele and shunt insertion. Childs Nerv Syst 20(2):107–9. https://doi.org/10.1007/s00381-003-0853-7